

HEAVY ISOTOPE COMPOSITION OF OXYGEN IN ZIRCON FROM SOIL SAMPLE 14163: LUNAR PERSPECTIVE OF AN EARLY OCEAN ON THE EARTH. A.A. Nemchin¹, M. J. Whitehouse², R.T. Pidgeon³ and C. Meyer⁴, ¹Western Australian School of Mines, Curtin University of Technology, Bentley Western Australia, 6102, Australia. ²Laboratory for Isotope Geology, Swedish Museum of Natural History, S-104-05 Stockholm, Sweden. ³Department of Applied Geology, Curtin University of Technology, Bentley, Western Australia, 6102, Australia. ⁴NASA Johnson Space Center, Houston, Texas, USA.

Thirty oxygen analyses of a large (sub-millimetre) zircon grain from the lunar soil sample 14163 have been determined using CAMECA 1270 ion microprobe.

The sample 14163 was returned from the Fra Mauro region by Apollo 14 mission. It was collected at the end of EVA-1, northwest of the Lunar Module by scoop; totalled 7129.8 g and represents mixed material from the upper several cm of the regolith. The Fra Mauro formation is interpreted as throwout produced during collision, which formed the Imbrium basin. The sample is strongly enriched in KREEP-type material compared to the Apollo 11 and 12 soils.

Zircon grain of 0.6-0.8 mm in size extracted from the sample was imaged using CL detector fitted to the Philips Electron Microscope in order to reveal internal structure. Secondary electrons and CL images (Fig.1) demonstrate absence of inclusions and internal homogeneity of analysed zircon grain. This homogeneity is confirmed by the six REE analyses, which show similarity of concentrations across the grain and the patterns characterised by very strong depletion in LREE, absence of Ce anomaly and strong negative Eu anomaly. All these features are common in lunar zircons (e.g. Whitehouse and Kamber, [1]). The homogeneity of analysed zircon grain is further demonstrated by two U-Pb analyses, which show indistinguishable and very low concentrations of U (16 and 18 ppm) and Th (8 and 9 ppm) and concordant U-Pb systems with ²⁰⁷Pb/²⁰⁶Pb ages of 4243±28 Ma (2 sigma) and 4235±28 Ma. Average of these two analyses can be considered as the best estimate of the grain's age and is equal to 4239±20 Ma.

Oxygen isotopes have been analysed during two sessions. The first set of data was collected using the original mount where the grain was set in the resin attached to the glass slide. This resulted in the two complications: (i) standard zircon has to be analysed from the separate mount and (ii) the lunar zircon grain was raised in the holder compared to the standard. In order to investigate, if the elevated oxygen compositions observed during this session could have resulted from this difference in geometric configuration during the standard and sample analyses, the lunar zircon was extracted from the original mount, remounted with the standard chip in the new resin disk and reanalysed during the second session.

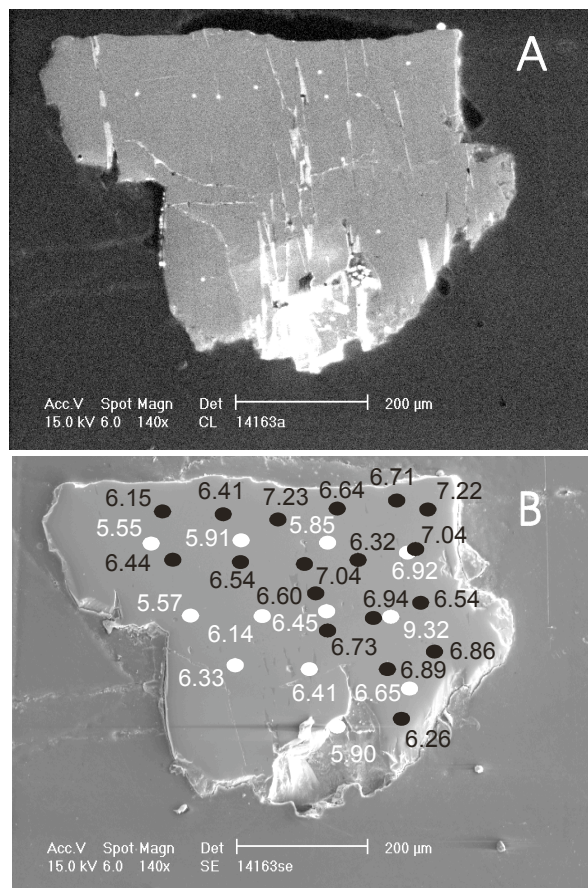


Figure.1. CL (A) and SE (B) images of grain 14163 with $\delta^{18}\text{O}$ values for the first (black) and the second (white) analytical sessions

All analyses made during the first session show $\delta^{18}\text{O}$ values heavier than 6.0‰. The second set of data has a wider spread of $\delta^{18}\text{O}$ values with some values as low as 5.6‰. Nevertheless, a half of observed $\delta^{18}\text{O}$ values in this set is also higher than 6.0‰. Slightly lighter oxygen compositions observed during the second session indicate possible dependence of measured $\delta^{18}\text{O}$ values on the geometry of analysed samples. One analytical spot in the second set of data shows exceptionally high value of $\delta^{18}\text{O}$ equal to 9.3‰. However, investigation of analytical pits under the electron microscope revealed a few microns long void on the side of the pit (Fig. 2), suggesting that the observed

heavy $\delta^{18}\text{O}$ value is an analytical artefact and highlighting once again the conclusion of Cavosie et al. [2] that the measured oxygen isotope compositions can be very sensitive to any aberration in the shape of analytical pits. Nevertheless, the remaining analytical spots, even those with the heavy oxygen isotope compositions, do not show any abnormalities and the observed $\delta^{18}\text{O}$ values can be taken as representing the correct isotope composition of the zircon grain.

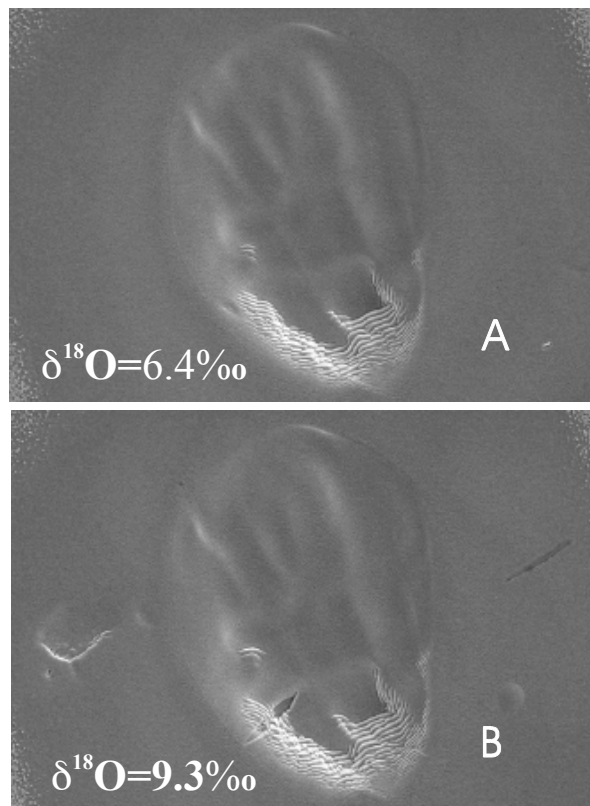


Figure 2. Example of ion probe pits; A – regular pit, B – irregular pit (void is visible in the left bottom part of the image), this irregularity is interpreted as the reason for the abnormally high $\delta^{18}\text{O}$

This oxygen isotope composition appears to be heavier than the values expected in the zircons equilibrated with the mantle derived melts (Fig.3). Significant number of analyses falls in the field described by Cavosie et al. [2] as ‘supracrustal’ zircons.

The heavy oxygen compositions observed in the zircon from the sample 14163 have significant implications for the models of early evolution of the Earth. Similar, heavy oxygen in the detrital zircons from the Jack Hills Sedimentary Belt in Western Australia were interpreted as an evidence for the presence of substantial volumes of liquid water on the surface of the Earth

as early as 4.4 Ga (e.g. Mojzsis et al. [4] and Wilde et al. [5]). This initial conclusion was further developed lately into the models that envisage very early cooling of the Earth (Valley et al. [6]) and suggest that within a few hundred Ma of formation the Earth has developed a pattern of crust production, erosion and sedimentary recycling similar to that common during the more recent history of the planet (e.g. Watson and Harrison [6]; Harrison et al., [7]).

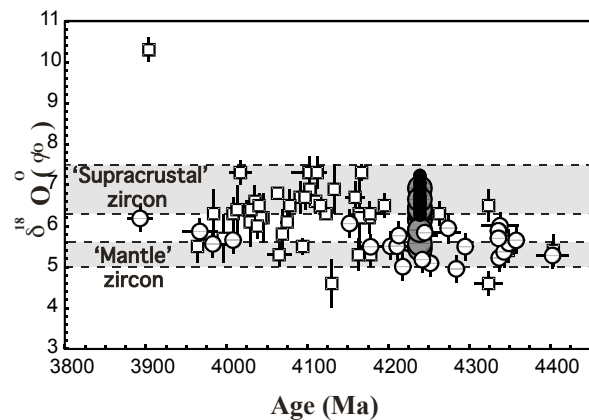


Figure 3. $\delta^{18}\text{O}$ vs. age for the Jack Hills and lunar zircons (open squares - Jack Hills zircons data from Cavosie et al. [2]; open circles – data from Nemchin et al. [3] for the zircons from the lunar breccia sample 14321; black circles – first set of analyses for the sample 14163; large dark grey circles – second set of data for the sample 14163). Fields for the ‘mantle’ zircon and ‘supracrustal’ zircon are after Cavosie et al. [2])

Presence of zircons with similar heavy oxygen isotope compositions on the Moon, which neither had liquid water or felsic crust similar to that on the Earth nor ever developed regime similar to plate tectonics, suggests that other mechanisms can be responsible for elevated $\delta^{18}\text{O}$ values in zircons. This implies that there is no support for the presence of an ocean on the surface of the early Earth and as the ocean appears to be an essential ingredient for the plate tectonics, there is no basis for belief that this mechanism was operating in the early history of the planet.

References: [1] Whitehouse M.J. and Kamber B. S. (2002) *EPSL* 204, 333-346. [2] Cavosie A.J. et al. (2005). *EPSL*, 235, 663-681. [3] Nemchin A.A. et al. (2006). *Geochim. Cosmochim. Acta.*, in press. [4] Mojzsis S.J., et al. (2001) *Nature* 409, 178-181. [5] Wilde S.A., et al. (2001) *Nature* 409, 175-178. [6] Watson E.B. and Harrison T.M. (2005) *Science* 308, 841-844. [7] Harrison T.M. (2005) *Science* 310, 1947-1950.